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## Simulating atmosphere flow for wind energy applications with WRF-LES

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Forecasts of available wind energy resources at high spatial resolution enable users to site wind turbines in optimal locations, to forecast available resources for integration into power grids, to schedule maintenance on wind energy facilities, and to define design criteria for next-generation turbines. This array of research needs implies that an appropriate forecasting tool must be able to account for mesoscale processes like frontal passages, surface-atmosphere interactions inducing local-scale circulations, and the microscale effects of atmospheric stability such as breaking Kelvin-Helmholtz billows. This range of scales and processes demands a mesoscale model with large-eddy simulation (LES) capabilities which can also account for varying atmospheric stability.

Numerical weather prediction models, such as the Weather and Research Forecasting model (WRF), excel at predicting synoptic and mesoscale phenomena. With grid spacings of less than 1 km (as is often required for wind energy applications), however, the limits of WRF's subfilter scale (SFS) turbulence parameterizations are exposed, and fundamental problems arise, associated with modeling the scales of motion between those which LES can represent and those for which large-scale PBL parameterizations apply. To address these issues, we have implemented significant modifications to the ARW core of the Weather Research and Forecasting model, including the Nonlinear Backscatter model with Anisotropy (NBA) SFS model following Kosović (1997) and an explicit filtering and reconstruction technique to compute the Resolvable Subfilter-Scale (RSFS) stresses (following Chow et al, 2005). We are also modifying WRF's terrain-following coordinate system by implementing an immersed boundary method (IBM) approach to account for the effects of complex terrain. Companion papers presenting idealized simulations with NBA-RSFS-WRF (Mirocha et al.) and IBM-WRF (K. A. Lundquist et al.) are also presented.

Observations of flow through the Altamont Pass (Northern California) wind farm are available for validation of the WRF modeling tool for wind energy applications. In this presentation, we use these data to evaluate simulations using the NBA-RSFS-WRF tool in multiple configurations. We vary nesting capabilities, multiple levels of RSFS reconstruction, SFS turbulence models (the new NBA turbulence model versus existing WRF SFS turbulence models) to illustrate the capabilities of the modeling tool and to prioritize recommendations for operational uses. Nested simulations which capture both significant mesoscale processes as well as local-scale stable boundary layer effects are required to effectively predict available wind resources at turbine height.

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